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Central Radon Data Base and Digitized Bedrock Map of
U.S. EPA (Environmental Protection Agency) Region 1

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A CENTRAL RADON DATA BASE
AND
DIGITIZED BEDROCK MAP
OF
U.S. EPA REGION I

National Network for Environmental Policy Studies Fellowship

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Disclaimer

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EXECUTIVE SUMMARY

Lifetime exposure to high indoor radon gas levels contributes to an increased risk of lung cancer. Geologic parameters are thought to be predictive factors of both well water and indoor radon levels. Therefore, both because radon is an important environmental risk and because risk communication is likely to play a central role in EPA's policies for radon related risks, a project was undertaken to develop appropriate radon risk communication strategies. EPA's Region I radon data base was updated and an existing Bedrock Geologic Map was digitized.

The research entailed compilation, management, and evaluation of existing data on domestic radon levels. This work required the cooperation of radon programs throughout Region I states. The updated data base has geographic capabilities and can be used to gain a clearer picture of areas with high radon levels.

This project may prompt further reeseach with the ARC/INFO system used to produce the bedrock map. Future investigation of radon using the data base and digitised map might include:

- * analysis of data before and after adjusting for differences between state and vendor data
- * measurement of variance of radon measurements within geographic regions
- * measurement of variance of radon levels within zip code/town boundaries
- * validation of cancer risk estimates based on radon levels and demographic data
- * validation of geologic model predictive factors for estimating radon levels
- * validation of soil permeability as a predictive factor for estimating radon levels
- * evaluation of climate and precipitation as predictive factors for estimating radon levels.

This project was developed by Project Officer Tom D'Avanzo (Region I - Air Mangement Division), with assistance from EPA Region I radon representatives Byron Keene and Stan Rydell. Funding for the project was provided through the National Network for Environmental Policy Studies at U.S. EPA.

INTRODUCTION

Radon-222, a radioactive isotope, is a decay product of Uranium-238 and the direct progeny of Radium-226. Uranium-238 occurs naturally in rocks and soils. While Uranium-238 and Radium-226 are relatively immobile, Radon-222 (radon) readily emanates as an inert gas into groundwater and air from surrounding bedrock and soil.

Low levels of radon are present everywhere. Radon becomes a threat to human health when it enters the indoor environment. Radon is a gas and can therefore migrate through fractures in bedrock and air space between soil particles, making its way into homes. Additionally, radon is moderately soluble in water and so may also enter homes through groundwater. The radon in groundwater is released indoors when water is used in the home.

The potential health threat from radon is an increased risk of lung cancer. Although radon is inert, it decays to chemically reactive isotopes that can attach to particulates in the air. These isotopes may then be inhaled and lodged in the lungs where they undergo further radioactive decay. This decay irradiates the lung tissues and can lead to lung cancer (1). The EPA estimates that 5,000 - 20,000 lung cancer deaths per year can be attributed to radon.

Comprehension of the risks and consequences that accompany radon exposure allows better prediction of public reaction to facts about radon. Subsequently, we can design public education programs that both stimulate the apathetic persons, yet do not create panic. Knowledge of the effects of radon exposure permits us to direct our risk communication strategies toward the most susceptible sector of the public. Research with a compiled data base can convey an understanding of suitable risk communication strategies directed at appropriate populations by producing accurate communication instruments which are sensitive to the needs of the public. The need here is reduction of domestic radon exposure. A full understanding of who we want to reach, where they are located, and how to display the information most effectively, will be enhanced by a central data base and associated geographic information system output.

An updated radon data base provides a framework for future comparative evaluations and historical documentation, and a foundation upon which we foresee its growth for future radon research. A digitised bedrock map can be used in the future to describe areal distributions and trends of radon within Region I, as well as point out areas of potentially high radon risk for further investigation.

DATA BASE

There are presently a variety of private and public data sets of radon measurements. The format and quality of these data points are varied. Both the EPA and other users of radon data bases can benefit from a screening and consolidation of these results. One goal of this project was to create a 'master' data base where all screened and cleaned files are kept together, yet each file necessarily separate from the other. This data base is expected, with the assistance of Region I State programs, to be updated periodically. These efforts augment the efficacy of all existing data bases of radon results.

Consultation with Byron Keene, EPA radon representative, led to the following proposed minimum criteria for suitable air measurements of radon levels in the 'master' data base:

type of measurement device: Type of measurement device used when taking measurement (e.g.; charcoal canister, alpha track detector).
device #: I.D. number of measurement device used - This will prevent repeated listings of a measurement in the data base.
zip code: Zip code area in which the measurement was taken.
town: Name of town in which measurement was taken.
building type: Type of building in which measurement was taken (e.g.; a ranch style house, apartment building, several floor house).
floor of measurement: On which floor was the measurement taken - basement, first, or second floor? The basement is recommended as it provides the most accurate depiction of actual radon levels entering homes.
date of measurement: The date, month, and year of measurement.
start and stop times: The times at which the measurement was started and concluded.
recorded level of radon: The level of radon in the home in pCi/liter or working levels.

This data format is critical to ensure the capability, growth, and range of future radon projects that use this data base.

The first step in collecting all existing data files was to identify all separate data sources - these include State Radiation Control Programs and private vendors. A majority (18/30) of the New England based vendors listed in the "Radon/Radon Progeny Measured Proficiency Program" report were contacted. One hundred percent of the vendors contacted are interested in assisting both the states and EPA in gathering all existing radon measurements. Several larger firms are already in contact with, and supplying data to, State programs.

Two problems exist with vendor data. The first is that much of the data does not meet the requirements listed above. The second is that a majority of these data points are not keyed into a computer file. If each state in Region I were to contact those vendors in their respective states and specify both the format and a frequency with which these sources might provide new data, we may overcome the first problem - arguably the largest obstacle to the completion of a central data base. The second problem, keypunching, is more a problem of logistics and will need to be worked out by EPA and State officials.

All suitable data from Region I was gathered and modified. The modified radon data files were adapted to a format acceptable as input to the ARC/INFO system, which is used to graphically display results.

The data base is currently in Reflex format on separate (by state) floppy discs. It will be loaded under a separate directory onto a hard drive by Byron Keene (since he is the one who most needs to know its location). The data presently in ARC/INFO are the geometric means of data points associated with their respective zip code. Any information held in ARC/INFO should not be regarded as the 'nest' for the data base.

What follows is a list of number of data points currently in the data base.

State	Air	Water**
Connecticut	1441-(EPA/State screening survey thru 5/88)	99
Maine	771-(State data - not updated since 8/87)	
Massachusetts	1603-(EPA/State screening survey thru 5/88)	112
	3034-(vendor)	
New Hampshire	616-(from local health offices and survey based on EPA screening protocol)	347
Rhode Island	425-(EPA/State screening survey thru 5/88)	127
Vermont*	272-(vendor)	380
	8162	1065

* - Several vendors have presented data for which there are several erroneous zip codes for a town.

** - Water data has no specific source, but rather has been gathered from various, inconsistent sources.

The radon in water measurements are subject to a number of factors that make their use difficult. The factors include source of water, geologic strata in contact with the water, well characteristics, and amount of fracturing of well bedrock. Much of the water data collected to this point is not suitable because it is incomplete at best. The information concerning well characteristics (well capacity, yield of well, and bedrock type and thickness) are unknown, yet necessary to accurately determine potential for radon hazard. Therefore it might be wise to delay the use of water data in this study until greater numbers of water data are gathered from designated sources. This would prevent the problems associated with statistical analyses of small sample sizes, as well as provide data gathered in a consistent fashion.

ARC/INFO

ARC/INFO is a general purpose geographic information system (GIS). It consists of two major groups of software; ARC software modules manage the geographic component of the data base while INFO manages the attribute data that describe what the map features are. INFO is a relational data base management system and can be used independently from ARC.

It supplies a set of programs to effectively encode, update and investigate environmental data. Maps are digitized and stored as a series of geographic overlays. The vector format of the digitizing maintains the original map's resolution. Once a map has been digitized, attribute data may be added, allowing a user access to both geographic and physical components of the data.

The ARC/INFO system provides a number of analytical functions. Maps may be overlaid to a) examine the coincidence of data points, b) perform proximity analyses, c) reclassify data, and d) yield derivative data results.

The ARC/INFO system can be used as a powerful tool for radon risk communication. ARC/INFO can present the geographic/physical data in a variety of formats. The digital maps may be presented at any scale, in color, on both paper and mylar. The various ways in which the data can be visually presented should be examined in order for it to properly convey information about the radon situation to various target audiences. Research of the results of prior EPA risk

communication studies should be made to ensure the most appropriate presentations (2).

BEDROCK MAP

The digitized map is based upon a generalized geologic map of New England, originally compiled by Wm. J. Olszewski Jr. for Dr. E. L. Boudette of the University of New Hampshire. It outlines the geologic distribution and lithologies of the major igneous, gneissic, and some sedimentary and volcanic rocks of Region I. It is a working map of the basic geology of many rock types in New England, digitized for the explicit purpose of radon studies. The map was produced to identify areas of possible or existing radon hazard and to help define areas for more detailed work.

As mentioned earlier, radon is derived from the radioactive decay of Uranium. Therefore a grasp of the apportionment and geology of Uranium bearing rocks is necessary to comprehend radon distribution. This map is designed to outline Uranium distribution in New England rocks.

The map is digitized at a scale of 1:1,000,000. Due to the large scale, the original mapmakers generalized and simplified the large scale aspects of New England Geology.

New England is geologically diverse. Many geological regions have potential for elevated radon levels (as determined by geologic factors, which include Uranium distribution). When identification of specific rock groups was undertaken, the mapmakers partitioned New England rock types into eleven groups. These groups include all plutonic rocks, gneissic rocks making up a core of gneiss complexes and some stratified gneisses, and unmetamorphosed sedimentary basins. These categories cover nearly all of the major sources for radon, especially binary granites, alkalic plutonic, gneiss and granitic gneisses. Geologic formations which have been subjected to very high pressures and temperatures (igneous and metamorphosed) are believed to have higher concentrations of uranium minerals. Granites are most likely to yield the highest levels of radon (3).

The use of this particular bedrock map which has geologic units assembled into broader classes of geology, allows for more inclusive generalizations of the connection between radon and bedrock types. The generalizations are necessary due to the high likelihood of elevated radon levels that might be due to pockets of bedrock that are higher in Uranium content than the broad class of bedrock by which they are surrounded (4).

The ultimate source of radon is the radioactive decay of Uranium. This fact and other geologic parameters are thought to be predictive factors of well water and indoor air radon levels. Therefore, in most instances, radon in air and in groundwater should show a direct correlation with Uranium in rocks and soils in the environment. Data from State surveys has indeed shown that, in most cases, the use of geology to predict areas where indoor radon may be a particularly serious problem can be effective (1). In general, we expect to find similar results with our digitized map and data sets. Any discrepancies (where the correlation does not exist) might be partially explained by the mobility of Uranium in groundwater which may influence total radon production.

If the distribution of water and indoor air radon levels of Region I can be accurately predicted, the information will provide a means to prioritize areas and target populations in Region I for further research. The information would then be presented in the form of maps. The bedrock map and subsequent displays of the correlations that exist would be produced using the ARC/INFO system.

The actual details as to how the bedrock map can be used to both predict radon levels and communicate risk will become clear as the maps to be presented are developed using ARC/INFO.

FURTHER RESEARCH

This study has just begun to scratch the surface of potential benefit that can be gained using a central data base with a digitised bedrock map of New England. Despite this project being in its initial stages, the work has sparked discussions of further areas to explore with the ARC/INFO system and our radon data base. The results from a continuation of this study will provide valuable information needed to coordinate appropriate regional risk communication responses to the radon issue.

A first step in further research using the data base should be an examination of the data itself. An analysis of all the raw data in the data base and the same data adjusted for differences between state and vendor measurement practices should be conducted to see if discrepancies in collection technique effect the measurements. If a difference exists, the adjusted data will be used. This will provide us with a larger data/sample size.

The next step would be the application of this data to our bedrock map, examining the variance within geographic regions - preferably areas of one type of bedrock, rather than zip code areas which may encompass several rock types. This should be done by taking the log of each data point within one cell, and estimating the standard error of the mean. This will account for varying sample sizes in the cells. The variance of radon levels within a geographic region can be used to validate the accuracy of geologic model predictive factors that estimate radon levels.

From here, the primary use of the air and water radon data and the digitized map will be to identify possible regions of elevated indoor radon concentration for further investigation. Statistical investigations should be made to identify geologic factors that explain the reported radon measurements. In this way, a region's bedrock under a home, or entered by a well, may delimit the range of potential radon levels.

It has been suggested that water data will correlate best with bedrock geology, however, this is dependent on water data for which complete records of well characteristics are on file. Therefore, it would seem that the air data might prove to be the better of the two to work with at this time.

While for no factor related to radon levels is there any data that is completely digitized, there is some that is on its way to completion**. One factor involved in radon transport that is currently being digitized is soil taxonomy. It is clear that soil type and porosity are important factors in the flow of soil gas, and hence, radon. Using digitised soil maps, the data and determined variance for a soil region can be used to validate soil permeability as a predictive factor for estimating radon levels.

Another factor of interest is climate. Increased temperatures decrease radon adsorption to soil materials. Therefore, climate data might be of interest. While there are no drastic climate changes in New England, climate data associated with radon measurements might prove useful if we compare Region I with another U.S. EPA region. Additionally, precipitation data might also be useful to see if areas of heavy rainfall do indeed have increased radon levels as some studies suggest.

Finally, regarding health effects, it may be useful to examine demographic data and epidemiologic data (ie; lung cancer rates) with appropriate radon data sets. Knowing radon levels and population densities, we can develop cancer risk factors. We can then use ARC/INFO to validate these cancer risk estimates based on digitised demographic and radon level data. Demographic cancer statistics can be obtained from cancer registries. However, looking at epidemiologic data is not straightforward. Doing such a crosssectional study requires data that can serve as appropriate indicators. An exercise such as this mandates an initial crude analysis to see if an association exists. If no association exists, the data should be reevaluated to see what factor might be responsible for the negative confounding (removal of association).

Limitations of these types of studies, due to confounding, may restrict the ability to generalize results across Region I. Nonetheless, proper and carefully planned use of ARC/INFO may help in accounting for unexplained confounding.

** - [The digitizing of information is being done by U.S.G.S. offices, a handful of Universities and engineering firms, and state GIS groups. The Region I GIS group is in contact with these other GIS centers and is aware of their progress.]

N.B. - It should be noted that the processes utilised in this project were part of an ongoing learning process. In addition, the digitizing of the bedrock map was a far greater task in and of itself than was originally expected. Nonetheless, the data base and complete bedrock map are available for others to gain general ideas of where radon is a problem.

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